



Asteroid Redirect Mission Concept Overview

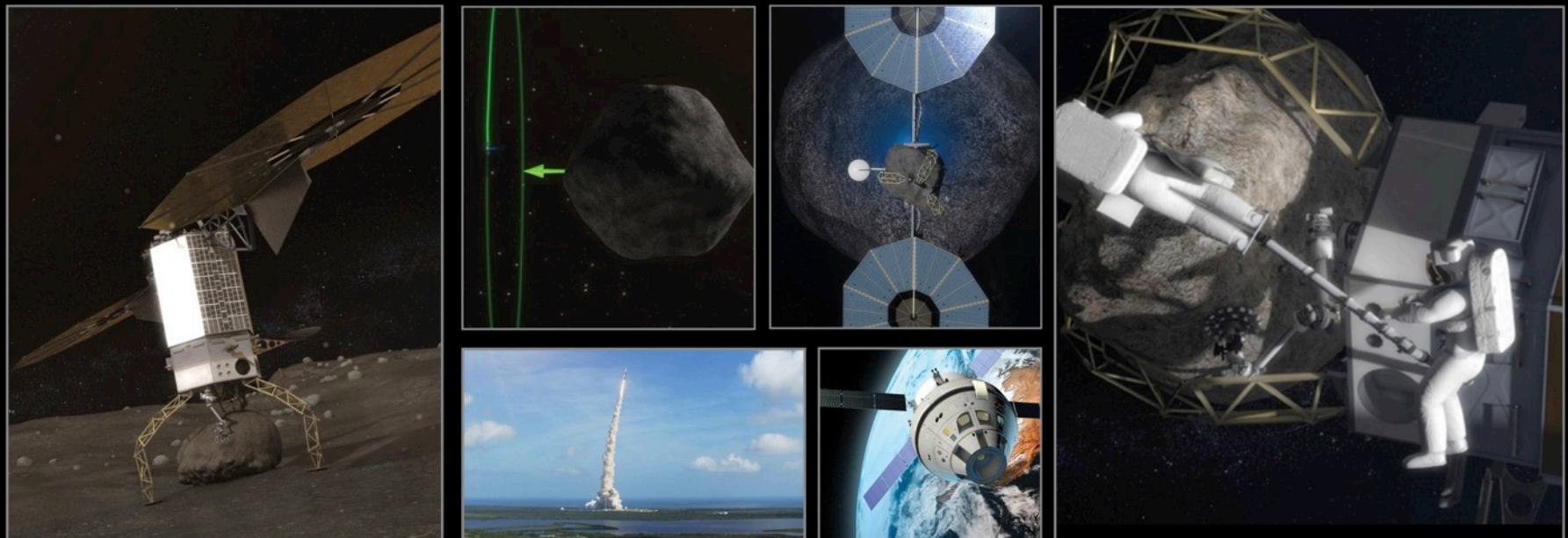
Michele Gates (NASA HQ)

Paul Abell (NASA JSC)

2015 SSERVI Exploration Science Forum

NASA Ames

July 22, 2015



Asteroid Redirect Mission: Three Main Segments

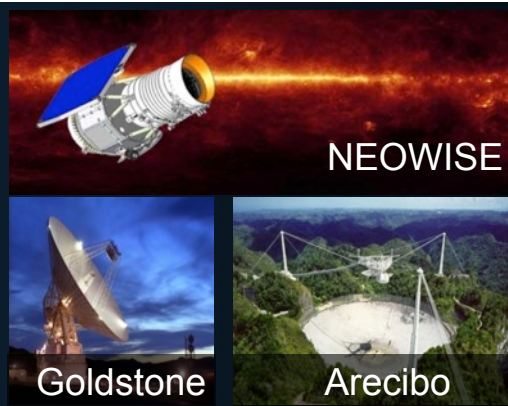


IDENTIFY

Ground and space based assets detect and characterize potential target asteroids



Pan-STARRS



NEOWISE



Goldstone



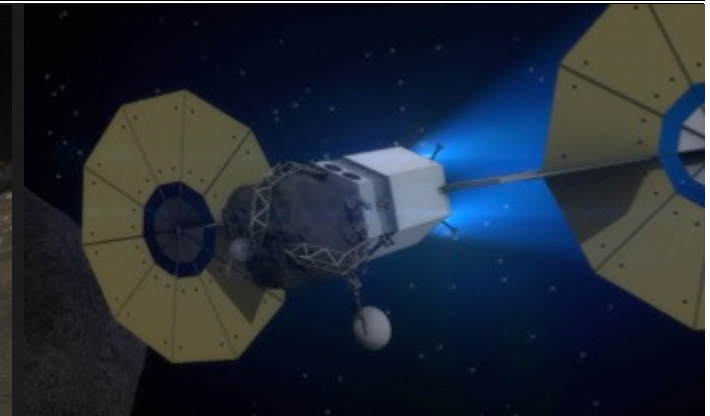
Arecibo



Infrared Telescope Facility

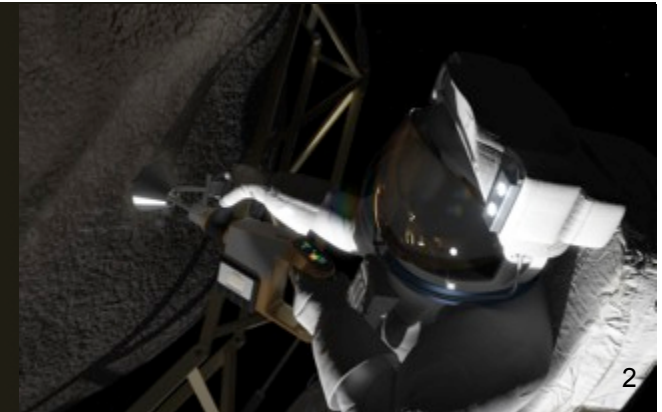
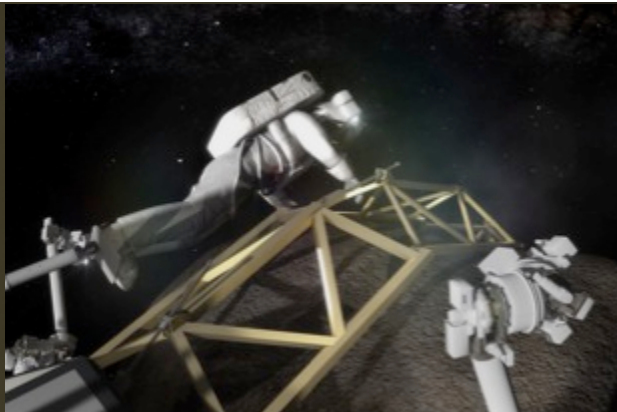
REDIRECT

The Asteroid Redirect Robotic Mission (ARRM) uses solar electric propulsion (SEP) to deflect an asteroid and return a boulder to cis-lunar space



EXPLORE

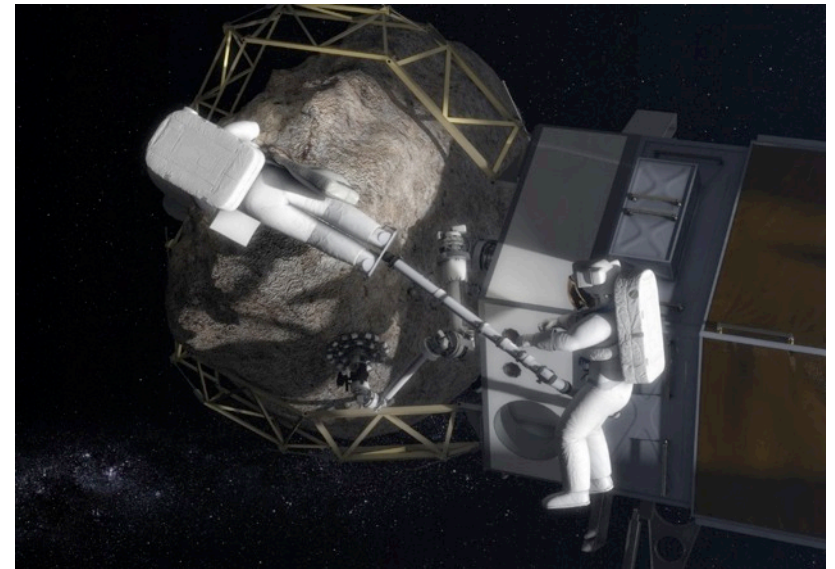
Crew launches aboard SLS rocket, travels in Orion spacecraft to rendezvous with robotic vehicle, conducts EVAs on boulder and returns samples to Earth



Objectives of Asteroid Redirect Mission



1. Conduct a human exploration mission involving in-space interaction with an asteroid boulder in the mid-2020's, providing systems and operational experience required for human exploration of Mars.
2. Demonstrate an advanced solar electric propulsion system, enabling future deep-space human and robotic exploration with applicability to the nation's public and private sector space needs.
3. Enhance detection, tracking, and characterization of Near-Earth Asteroids, enabling an overall strategy to defend our home planet.
4. Demonstrate basic planetary defense techniques that will inform impact threat mitigation strategies to defend our home planet.
5. Pursue a target of opportunity that benefits scientific and partnership interests, expanding our knowledge of small celestial bodies and enabling the mining of asteroid resources for commercial and exploration needs.



Asteroid Operations Phase Overview

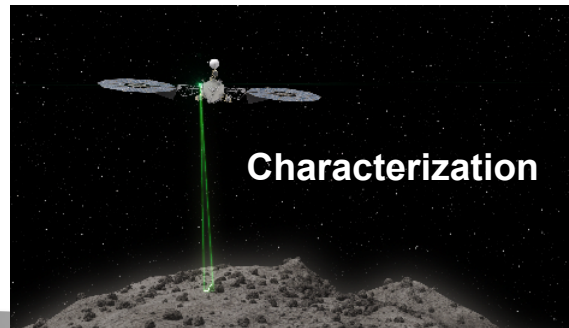
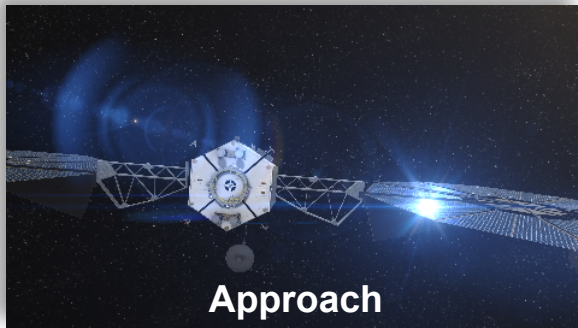


Approach
2 weeks

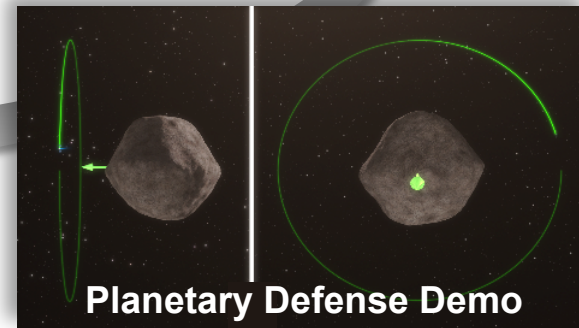
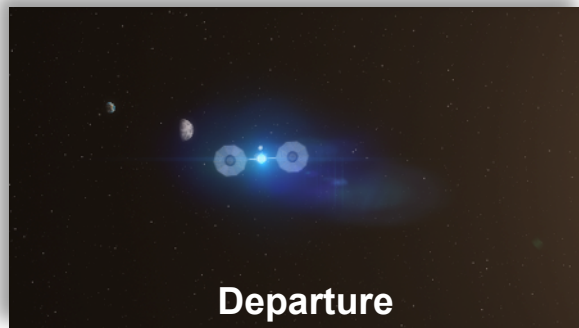
Characterization
2 months

Boulder Collection
2.5 months
(allocated)

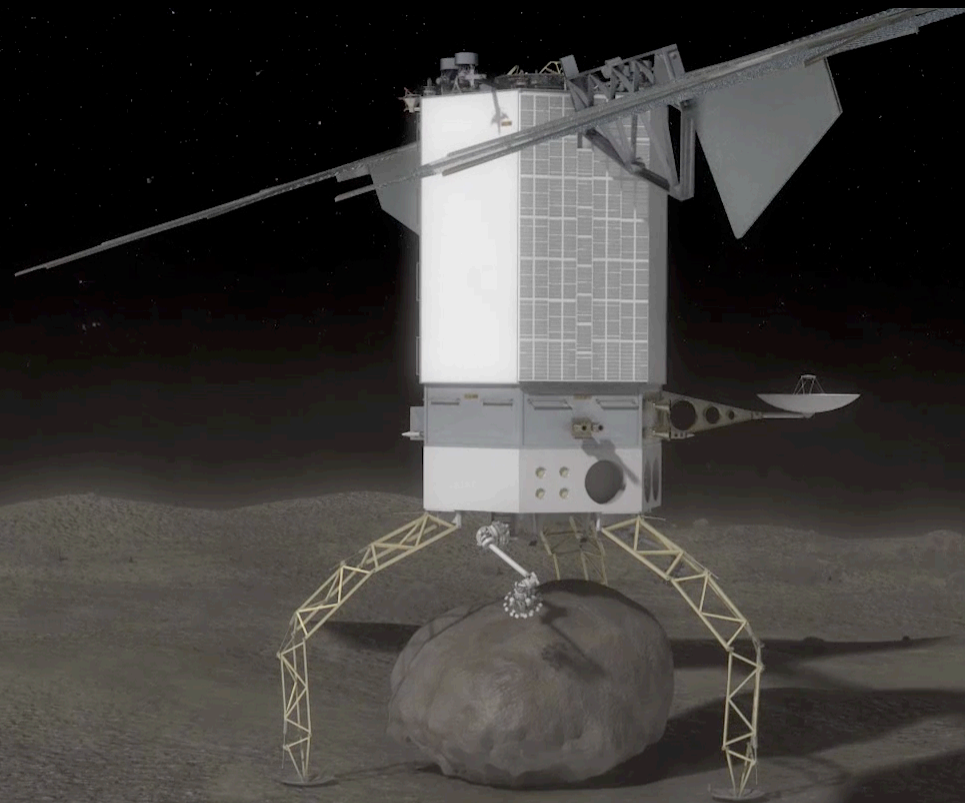
Planetary Defense Demo
5 months



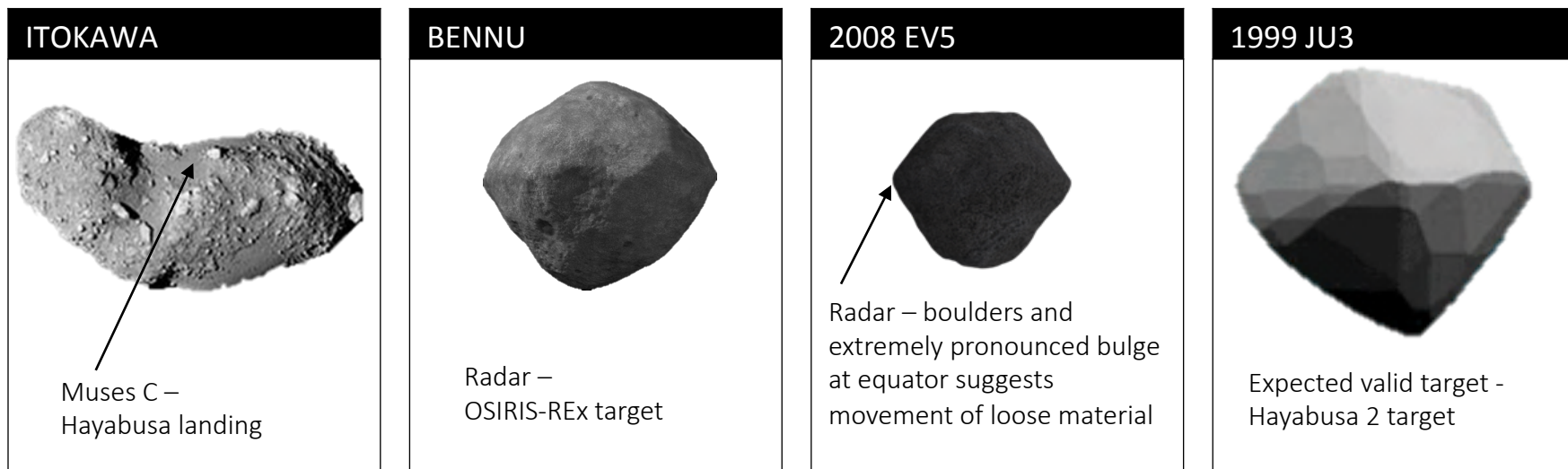
Note: Asteroid operations timeline varies depending on target asteroid. Times shown are for 2008 EV₅: total stay time of 10 months with an additional 3 months of margin.



ARM Operations Video



Current Candidate Parent Asteroids



Asteroids not to scale

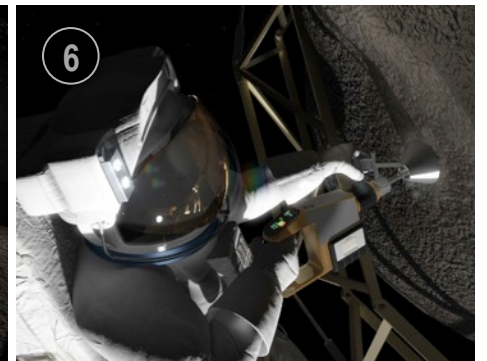
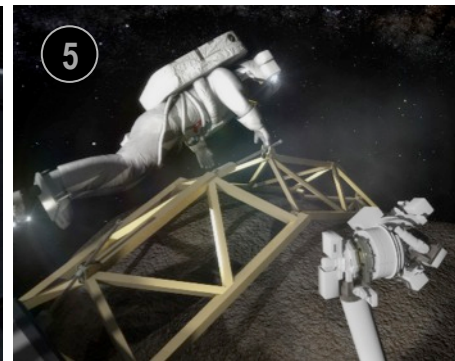
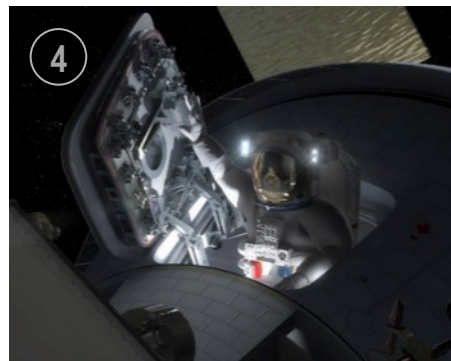
Comparison of current candidate parent asteroids

	Itokawa	Bennu	2008 EV ₅	1999 JU ₃
Size	535 x 294 x 209 m	492 x 508 x 546 m	420 x 410 x 390 m	870 m diameter
V_{∞}	5.68 km/s	6.36 km/s	4.41 km/s	5.08 km/s
Aphelion	1.70 AU	1.36 AU	1.04 AU	1.42 AU
Spin Period	12.13 hr	4.297 hr	3.725 hr	7.627 hr
Type	S	B (C-grp volatile rich)	C (volatile rich)	C (volatile rich)
Precursor	Hayabusa (2005)	OSIRIS-REx (9/2016 launch, 8/2018 arrival)	None currently planned (boulders implied from 2008 radar imaging)	Hayabusa 2 (launched 12/3/2014, 7/2018 arrival)

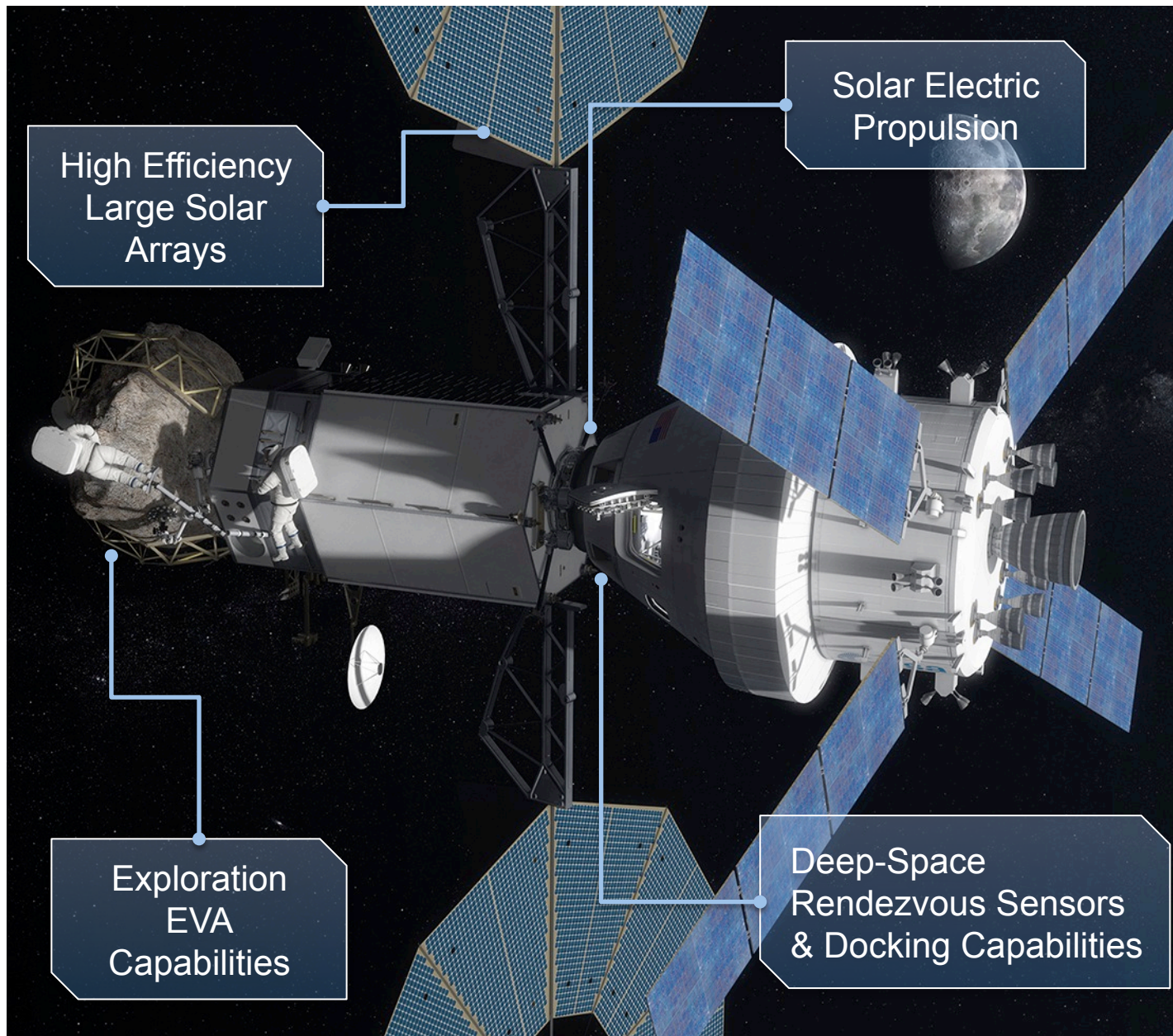
NASA continues to look for additional targets in accessible orbits.

Reference ARRM Target

Asteroid Redirect Crewed Mission (ARCM) Overview



ARM: A Capability Demonstration Mission



IN-SPACE POWER & PROPULSION:

- High efficiency 40kW SEP extensible to Mars cargo missions
- Power enhancements feed forward to deep-space habitats and transit vehicles

EXTRAVEHICULAR ACTIVITIES:

- Primary Life Support System design accommodates Mars
- Sample collection and containment techniques
- Follow-on missions in DRO can provide more capable exploration suits and tools

TRANSPORTATION & OPERATIONS:

- Capture and control of non-cooperative objects
- Rendezvous sensors and docking systems for deep space
- Cis-lunar operations are proving ground for deep space operations, trajectory, and navigation

Findings from the SBAG ARM SAT



- Two important findings from the SBAG Asteroid Redirect Mission Special Action Team (ARM SAT):

“Involvement of a science team is critically important to maximize the science, including during the concept development portion of the mission. The science team should be involved in all aspects of the mission and its development, including target selection, scientific instrument development, the robotic asteroid encounter, and characterization and sampling by the crewed mission. The early application of the best available science insight can reduce complexity, cost, and mission risk. A science team, or science advisory group, should be integrated into current and ongoing ARM development efforts independent of there being any science objectives.”

“Involvement of the planetary defense community will be vital for optimal leveraging of the ARM mission for planetary defense studies. Involving the wider community in order to incorporate their expertise will help ensure that any planned demonstrations are correctly scoped for the available resources and allow the most efficient leveraging of independent programs already underway.”

- In response to these findings, NASA is organizing an **ARM Investigation Team (IT)**, which will be preceded by the **Formulation Assessment and Support Team (FAST)**. These teams will be comprised of scientists, technologists, and other qualified and interested individuals to help plan the implementation and execution of ARM.

Formulation Assessment and Support Team (FAST)



- Formulation Assessment and Support Team (FAST) will consist of NASA and non-NASA participants who will:
 - participate in requirement formulation efforts during the initial development phase of the Asteroid Redirect Robotic Mission (ARRM) in support of the ARRM Requirements Closure Technical Interchange Meeting (TIM) currently planned for mid-December of 2015
 - provide initial inputs for potential investigations and payloads related to the following four main areas:
 - **Science**
 - **Planetary Defense**
 - **Asteroidal Resources and In-Situ Resource Utilization (ISRU)**
 - **Capability/Technology Demonstration**
 - work in collaboration with ARM management and technical personnel at the participating field centers to provide input during the requirements definition phase of the ARRM, which includes spacecraft interfaces, requirements, and design considerations as they relate to the Asteroid Redirect Crewed Mission (ARCM).
 - provide input to NASA on potential payloads and partnerships.

Formulation Assessment and Support Team (FAST) Planned Structure and Milestones



- U.S. Membership
 - Approximately 12-15 unfunded participant members.
 - Composed of NASA and non-NASA participants plus Mission Investigator, Deputy Investigator, and Analysis and Integration Lead.
 - Final product will be in the form of a report to NASA
- Membership call was announced on July 7 via NSPIRES (**due date is August 7**).
- Funded travel planned for two in-person team meetings (kick-off and final) with 2-3 virtual meetings in between.
 - Kick-off meeting planned for mid-September 2015
 - Final meeting planned for mid-November 2015
- The final report of the ARM FAST will be submitted to NASA around November 20, 2015. The final report is expected to be released publically and available for comment. After the report is finalized FAST will be disbanded.

ARM Investigation Team (IT)



- The purpose of the multidisciplinary Investigation Team (IT) is to assist with the definition and support of investigations in the following four main areas as they pertain to the robotic and crewed segment objectives:
 - **Science**
 - **Planetary Defense**
 - **Asteroidal Resources and In-Situ Resource Utilization (ISRU)**
 - **Capability/Technology Demonstration**
- In the context of these four investigation areas, the IT will provide input into extensibility, commercialization, and partnership activities in close coordination with other agency efforts.
- The IT supports ARM program-level and project-level functions, provides technical expertise, and supports HQ interactions with the technical communities. Includes support of:
 - **Mission formulation (e.g., concept development for robotic and crew segments)**
 - **Mission design and vehicle development (e.g., asteroid landing/capture system)**
 - **Mission implementation (e.g., close proximity operations, crew sampling, etc.)**

Investigation Team Planned Structure and Milestones



- U.S. Membership
 - **NASA appointed Mission Investigator, Deputy Investigator, and Analysis and Integration Lead.**
 - **Selection of additional members**
 - **Nominally 50% NASA and 50% non-NASA membership**
 - **Team size and level-of-effort are TBD**
 - **Funds provided to cover participation and travel**
- International and Commercial Membership
 - **Invited guest members as mutually beneficial opportunities arise**
 - **All participation and travel expenses to be covered by their respective institutions**
- Planned membership call in January 2016 and team kick-off by mid-2016
- The initial term of membership will be nominally three years, but may be extended.

Examples of Investigation Team Inputs for ARM



- Assist in identification and remote characterization of additional targets and input into NEA target selection process.
- Assist in characterization and modeling of NEAs and their environments.
- Assist in the characterization and identification of desirable boulder attributes for capture and retrieval.
- Identify investigation opportunities within baseline mission capabilities and operations.
- Provide inputs on potential hosted, deployable, and secondary payloads.
- Provide input regarding regolith samples that may be acquired during surface operations via Capture Restraint System (CRS) contact.
- Provide plans for the processing, dissemination, and archiving of asteroid-related mission science data.
- Provide inputs into post-capture characterization and EVA planning and procedures.
- Identify investigations of the boulder that may be conducted during the return trip and subsequent operations in cislunar space (post-ARCM).
- Provide science support prior to and during ARCM EVA at the boulder.

ARM Areas of Interest and Opportunities



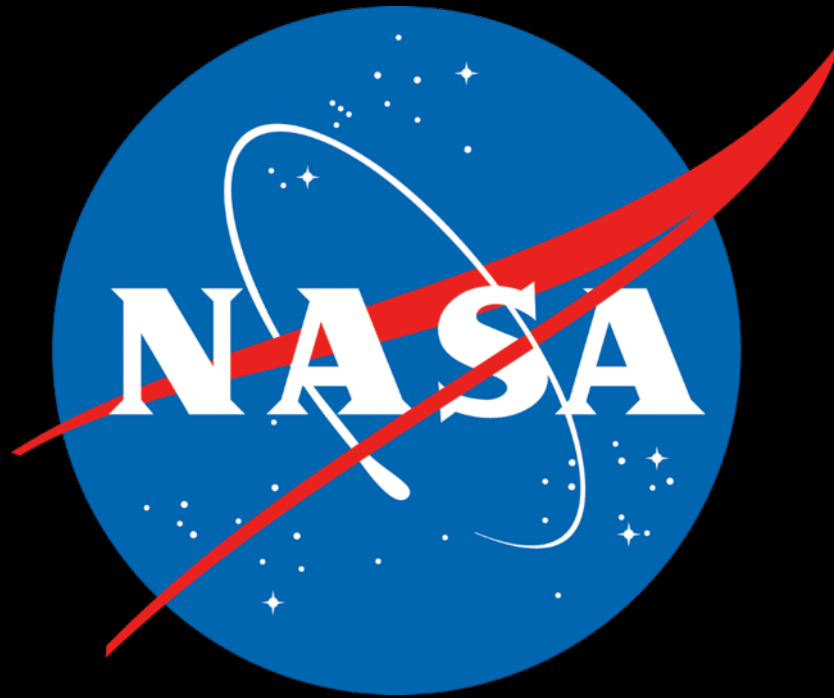
- NASA is pursuing commercial, academic, and international partnership opportunities within program cost, schedule, and technical constraints.
 - **Significant opportunities exist within baseline mission capabilities and operations.**
 - **Ongoing discussions regarding potential international partnerships.**
 - **Accommodations (mass, power, volume, and data) for hosted and deployable payloads on the Asteroid Redirect Robotic Mission (ARRM) spacecraft are currently planned, with the potential for secondary payloads on the launch vehicle.**
- Potential partnerships during the Asteroid Redirect Crewed Mission (ARCM) may be available in the future.

ARM FAST and IT inputs are important for successful requirements formulation and mission development and implementation.

Conclusions



- NASA is organizing an ARM Investigation Team (IT), which will be preceded by the FAST (Formulation Assessment and Support Team). These teams will comprise of scientists, technologists, and other qualified and interested individuals to help plan the implementation and execution of ARM.
- These teams will assist with the definition and support of investigations in the following four main areas as they pertain to the robotic and crewed segment objectives:
 - **Science**
 - **Planetary Defense**
 - **Asteroidal Resources and In-Situ Resource Utilization (ISRU)**
 - **Capability/Technology Demonstration**
- NASA is pursuing commercial, academic, and international partnership opportunities within program cost, schedule, and technical constraints.
 - Significant opportunities exist within baseline mission capabilities and operations.
 - Ongoing discussions regarding potential international partnerships.
- ARM is best implemented with continued engagement of the scientific and exploration communities.



<http://www.nasa.gov/asteroidinitiative>